Aerogel Dielectric Materials

Exceptional dielectric constants, volume resistivities, and dielectric strengths

Highly porous materials with unique nanostructures, aerogels exhibit unusual dielectric properties—properties more like those of a gas than of a solid. Their low dielectric constants, low loss tangents, and controllable thermal expansion properties will soon make aerogels the material of choice for thin films in high-speed, integrated digital and microwave circuitry. Thin aerogel films exhibit:

- Dielectric constants of 1.008 to 1.990 (3–40 GHz)
- Loss tangents of 10^{-4} to 10^{-2} (3–40 GHz)
- Volume resistivities of 10^{13} to 10^{15} Ω·cm
- Dielectric strengths of 120 to 140 kV/cm.

APPLICATIONS

- *Microwave strip lines*
- *Microwave circuits for radar and communication technologies*
- *Low-capacitance chip connectors*
- *Lightweight electronics packages*
- *Air-like suspension of microwave circuits*
- *Coaxial cable insulation*
- *Power-transmission, high-voltage insulators*
- *Spacers for electrodes in vacuum tubes*

Low dielectric constants

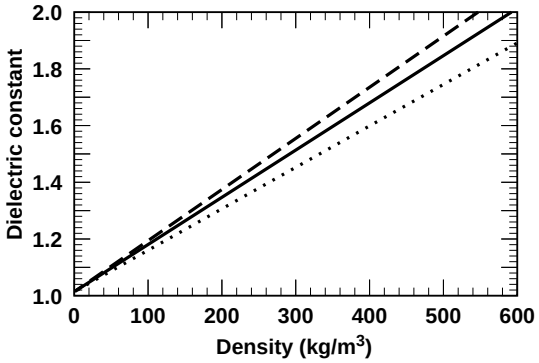
Our measurements of the real (dielectric constant) and imaginary (loss factor) parts of the complex permittivity as a function of density (see accompanying figure) demonstrate the low dielectric constants and relatively small losses for all aerogels. The dielectric constant for any aerogel less dense than 600 kg/m^3 is less than the dielectric constant of Teflon—the most commonly used low dielectric. We measured a dielectric constant of 1.008 for a silica aerogel with a density of 8 kg/m^3—the lowest dielectric constant ever measured for a bulk solid.

Superior volume resistivity

The dielectric conductivity of aerogels and its inverse, volume resistivity, are obtained from microwave measurements. For all aerogels, these volume resistivities are comparable to the best polymer insulating materials. Aerogels should exhibit good dielectric strengths against high-voltage breakdown.

High dielectric strength

We measured the dielectric strength at 300 K and 60 Hz for air-filled silica aerogels. Breakdown voltages were registered for different thicknesses of the aerogel. The average dielectric strength was 127 kV/cm (essentially independent of aerogel density); thus, aerogels should be effective, lightweight insulators for high-voltage applications.



Dielectric constant vs density values (18–40 GHz) for silica aerogel (dotted line), resorcinol–formaldehyde (solid line), and melamine–formaldehyde (dashed line).

Thin-film aerogel dielectric substrates

Thin aerogel films are excellent for electronic applications that require very low dielectric properties. We developed methods of fabricating aerogel films from 1 to 100 μm thick. We are developing processes for sealing, patterning, and metalizing both bulk and thin-film aerogels. Qualitative tests show that aerogels can be used with conventional photoresist techniques. By varying chemical composition and density, we can tailor the aerogel's properties to the desired application.

Aerogels also possess valuable complementary properties for electronics applications: they are lightweight with low thermal expansion and adequate thermal conductivity and mechanical strength.

Availability: Aerogels are available now. We are seeking industrial partners with whom we can develop commercial processes and prototype products.

Contact

Lawrence Hrubesh
Phone: (510) 423-1691
Fax: (510) 423-4897
E-mail: hrubesh1@llnl.gov
Mail code: L-320

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